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ference in the progress and development of the State. The most open communication is on the southeast, where lines can come from all directions to the only port of the State, Philadelphia. The long break in the South Mountain belt gives easy access to the Great Valley, and opens the way to the middle of the State. Three of the four gaps in the Blue Ridge are in that part of its extent lying in front of the coal fields, to which means of entrance is of the utmost economic importance. The fourth and last gap in the Blue Ridge is opposite the break in the South Mountain, and also in such a place as to be an important part of the gateway to the western part of the State. The gaps are absent only in that part of the Ridge where their need is not great. The transverse course of the Juniata offers a pathway through the otherwise unbroken ridges, from the gap of the Susquehanna to the Allegheny Front at a particular place where crossing is impossible. And, finally, on the western side of the Front, the Conemaugh and Castleman Rivers head near the only points where for miles in extent crossing by railroad is practicable, and offer easy routes for the roads through the broken country of the western district.

THE BIOLOGICAL EVIDENCE OF RIVER CAPTURE.*

BY

DOUGLAS WILSON JOHNSON.

Whenever one stream captures a portion of the drainage of a neighbouring stream, certain results are produced which become evidences of the capture which has occurred. By a study of these results we are able to tell much about the former relations of the streams affected, and may even learn the approximate time at which the change took place.

It will readily appear that river capture may produce two different classes of results: first, those which can be produced by nothing else than river capture, and which are therefore to be regarded as conclusive proofs of such capture; and, second, those which can be produced by other agencies as well, and which are therefore not in themselves proof of capture. In the study of drainage modifications in general, and in the study of any particular case of capture, it is a matter of prime importance to distinguish clearly between these two classes of results, in order that those who follow our work may fully understand the character of the evidence upon which our conclusions are based.

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* Abstract of a paper read before the Philadelphia meeting of the Association of American Geographers. The complete paper will appear in "Science," and a full discussion of the Tennessee problem in the Journal of Geology.

In the discussion of drainage modifications, different students of the subject have pointed out a variety of evidence leading to the conclusion that capture has occurred. One such line of evidence is that furnished by the distribution of fresh-water shells, which we may term the biological evidence of river capture. Two neighbouring streams may have characteristically different faunas inhabiting them. If a portion of the drainage of one stream is captured by a branch of the adjacent stream, the fauna of the captured one will be mingled with that of the captor. Such a commingling of faunas becomes one evidence of the capture.

This line of evidence has been advanced in support of several cases of supposed river capture, and has been widely accepted as a definite proof of capture. The conclusions arrived at are in some instances far-reaching in their effects, and it would seem very essential to weigh carefully the evidence upon which those conclusions are based. Especially is this true of evidence offered and accepted as conclusive in and of itself.

The biological evidence can be accepted as proof of river capture only if we grant that no other agency can effect the commingling of forms referred to. It is therefore pertinent to ask: Are there any other means for the dispersion of fresh-water shells besides river capture? If so, is there any reason why the shells in question may not have been so dispersed? And is there any evidence of such dispersal elsewhere, under conditions which preclude the possibility of river capture's having been the effective agent?

The first question must be answered in the affirmative. It is known that the young of many of the forms in question possess the power to attach themselves to the feet or feathers of birds, or to insects, or to plants carried away by birds, and that they may thus be transferred from the waters of one stream to those of another. It is believed that they may also pass from stream to stream across the low interstream areas near the sea in times of great floods, or that they may migrate along the shore itself. These and other means of dispersal are considered more in detail in another place, and it is only desired to call attention here to the fact that they exist.

According to those who are most familiar with the anatomy and habits of the special forms involved in the biological evidence as heretofore employed, there is no reason why they should not be dispersed in the ways above mentioned.

That these other means of dispersal are effective is shown by the fact that the same species supposed to prove the capture are elsewhere found inhabiting different streams, far distant from each other, under conditions which make it impossible that river capture should be held responsible for their location. Other similar forms have almost world-wide distribution, inhabiting different continents, necessarily having been dispersed by some of the other agents referred to, or by means concerning which we have no knowledge.

These general facts, which I have elsewhere discussed more fully, compel the conclusion that in its broadest terms the biological evidence of river capture is not conclusive in itself. We must make a careful study of the circumstances of each special problem; note the character of the divide between the two streams, to see whether it is favourable for the transfer of forms across it; examine the special forms under discussion, to see whether they are adapted to the various means of dispersal; ascertain whether those forms have elsewhere been distributed by some agent which could not have been river capture—in short, make a critical test of the evidence before using it.

Such a test has not been made in cases where this line of evidence has been most effectively employed, with the result that evidence, which is shown to be incompetent in the light of the distribution elsewhere of the species involved, has been accepted by many as a proof of river capture where positive evidence now available tends to show that capture did not occur. Thus, the fact that shells especially characteristic of the Tennessee River have been found in the Coosa and Alabama Rivers has been urged as proof that the Tennessee River formerly flowed southward by way of the Coosa and Alabama into the Gulf, and owes its present course to capture near the Chattanooga by a stream from the west. It appears, however, that the divide between the waters of the Tennessee and Coosa basins is low and insignificant, and so situated as to be peculiarly favourable for the transference of the shells from one stream into the other. Furthermore, it is seen that the same shells upon which the argument in favour of capture is based occur in other streams, where it is impossible to suppose that they have been transferred by river capture. If river capture is not responsible for their distribution in these last cases, then it is not possible to prove capture of the Tennessee on this evidence alone. Capture *may* be responsible for the distribution in such cases, but it *need not* be. It is believed that in the case of the Tennessee the distribution must have been effected independently of river capture.

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